

Fungal diseases of mushrooms and their control

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Although there are many fungal pathogens, only a few of them cause severe crop losses. The main diseases of concern are Dry Bubble (*Verticillium*, new name: *Lecanicillium*), Wet Bubble (*Mycogone*) and Cobweb (*Dactylium*, new name: *Cladobotryum*). Information is provided on disease symptoms and recognition as well as on disease prevention and control. Sometimes, laboratory identification is needed to distinguish between Dry and Wet Bubble, or to identify other pathogens such as bacteria (eg *Pseudomonas tolaasii*).



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Key recommendations

- Protect casing and casing operations from contamination by spore-laden water splash, dust and debris. Disinfect casing equipment and concrete areas before casing operations begin.
- Maintain growing rooms in good condition and be aware of the quality of walls and ceilings, especially where they meet. Coatings need to be controlled and repaired if needed, at least every three years. Ensure door seals and vents are in good condition – smooth, sealed surfaces and rooms are easier to clean and disinfect.
- Maintain the surroundings of the mushroom farm in good condition, avoiding the accumulation of organic matter (compost, casing soil, mushroom stalks) which can act as a reservoir and refuge for spore-laden debris and flies.
- Inspect mushroom beds regularly for disease, especially prior to watering and picking. Ideally, a dedicated disease team should be trained to treat all disease.
- Treat disease rapidly and appropriately before any watering of the crop to prevent the development of secondary infections. Watering over untreated disease is a major cause of disease spread.
- When Cobweb is present, turn off the air circulation fans when treating it or when watering rooms to minimise the possibility of dispersing the airborne spores around the room.
- When Dry Bubble is present, ensure that fly populations are monitored and kept under control.
- Ensure good hygiene practices are in place and being implemented correctly, for example, foot dips, alcohol hand gel, disinfection of picking equipment and use of disposable gloves and overalls, etc.
- Clean and disinfect concrete areas outside growing rooms at the end of every day to kill off any spore-laden contaminated dust and debris coming out of infected rooms.
- Cook-out crops thoroughly with steam before emptying (65-70°C compost temperature for a minimum of 8 hours), then clean and disinfect floors after emptying.
- If disease levels are very high, then (a) terminate crops early, (b) do not water crops between flushes, (c) reduce crops to two flushes, (d) review all hygiene measures to ensure they are being implemented correctly.



1. Mushroom crop affected by *Mycogone*

Dry Bubble Disease

Symptoms

A number of different symptoms occur depending on the time of infection. Small bubbles of tissue develop when mushroom pins are infected at a very early stage. When infection occurs during early mushroom development, then split stipes and partial mushroom malformations can develop. Wart-like growths can occur on the cap when older developing mushrooms are infected. When fully formed mushrooms are infected, for example, by water splash or flies, then grey-brown spots can develop on the mushroom caps.



2. Dry Bubble developing in a crop



3. Wart-like growths due to *Lecanicillium*

Disease spread and transmission

Lecanicillium spores are sticky and this allows them to become attached to dust, flies, casing debris and people (hands, clothing and footwear) as well as many kinds of surfaces (shelving, picking tools, floors, door handles, canteen areas). The spores can survive for quite a long time. The first infection in a mushroom crop will usually occur when the casing or casing equipment is contaminated either by windblown dust, flies or people. Single pieces of Dry Bubble will appear in the crop and if they are undetected or untreated they will produce masses of spores. The sticky spores will be spread further when the crop is watered; water splashes will contaminate

adjacent mushrooms as well as the shelving, the floor and other surfaces. More Dry Bubble Disease will develop in the next flush, as well as other symptoms such as partial malformations, wart-like growths and spotting, depending on the growth stages of the mushrooms on the bed.

Flies are attracted to the infected mushrooms and they too will spread the disease further. They move freely around the farm and between growing rooms, contaminating surfaces they land on, such as casing, casing equipment and freshly cased crops. In addition, each pregnant female fly that enters a freshly cased room will lay about 10-15 separate groups of eggs, which will lead to further infections as well as a growing population of flies.

Once the disease is established on the farm, there is a continuous supply of sticky spores that can cause a continuous cycle of disease symptoms, if left untreated.



4. Grey-brown spots due to water splash

Disease treatment

Clearly mark all areas to be treated. It is advisable not to remove any pieces of bubble, even with disposable gloves as this risks spreading the sticky spores further. Cover the diseased area to at least 5cm beyond the edge with strong paper tissue (double thickness) which has been dampened with water for easy handling and positioning. Historically, inverted plastic containers and salt were used for this purpose. If there are growing mushrooms beneath the paper, try to break the connection with the casing to stop them growing. Check treated areas regularly to make sure there has been no regrowth nearby. Where bubble symptoms occur over a wide area, with many dry bubbles, spotted and misshapen mushrooms close together, it means that an undetected piece of Dry Bubble Disease was watered over at the end of the previous flush and contaminated water splash has now infected a large area of the bed. This is difficult to treat effectively. Cover the area as before and consider terminating the crop at the end of the flush. Do not water again if taking to another flush. Hygiene procedures should be reviewed to ensure they are being followed.

Wet Bubble Disease

Symptoms

Wet Bubble Disease is caused by *Mycogone* and the symptoms can be similar to those caused by *Lecanicillium*. The main

symptom is the development of large undifferentiated and irregular masses of tissue. Other symptoms include severely malformed mushrooms with heavily swollen stipes and deformed caps, wart-like growths and cap spotting. Droplets

of amber colored liquid can appear on the surface of the bubbles and the tissue gets soft and rotten. In severe cases, white mycelium can grow out onto the surrounding casing which will turn brown as the spores mature.



5. Malformed mushrooms due to *Mycogone*

Biology and epidemiology

Mycogone produces two spore types, a small fragile short-lived spore and a larger, tougher long-lived chlamyospore. *Mycogone* occurs in nature on wild mushrooms and so the tough walled spores can be present in soil. The tough walled spores can survive in organic debris on mushroom farms such as compost and casing debris from infected crops. *Mycogone* outbreaks are, therefore, usually associated with contamination of the casing or water supply with soil or other dust and debris, resulting in the formation of the characteristic large misshapen masses of tissue.

If unnoticed or left untreated, the wet bubbles produce masses of small short-lived spores initially and then the larger tougher chlamyospores, and both will be spread by water splash onto the adjacent crop, as well as onto surrounding surfaces and floors. The spores will become mixed with casing and compost debris on floors and then be spread around the farm on footwear, as well as blown around the farm in the dust fraction. This contaminated dust and debris can cause new infections to develop if casing and casing equipment are contaminated or if shelving and growing rooms are not thoroughly disinfected between crops. The spores are not sticky and so are not spread by flies.

Disease treatment

Clearly mark all areas to be treated. Localised individual pieces of *Mycogone* can be removed carefully using a disposable glove or plastic bag. Once the piece of Wet Bubble is in the bag or glove, carefully invert the bag or glove over it, close it securely and dispose of safely. Cover the diseased area to at least 5cm beyond the edge of the patch with strong paper tissue (double thickness) which has been dampened with water for easy handling and positioning. Historically, inverted plastic containers and salt were used for this purpose. If there are growing mushrooms beneath the paper, try to break the connection with the casing to stop them growing. Check treated areas regularly to make sure there has been no regrowth nearby. Where Wet Bubble symptoms occur over a wide area, with many wet bubbles, spotted and misshapen mushrooms close together, it means that an undetected piece of Wet Bubble was watered over at the end of the previous flush and contaminated water splash has now infected a large area of the bed. This is difficult to treat effectively. Cover the area as before and consider terminating the crop at the end of the flush. Do not water again if taking to another flush. Hygiene procedures should be reviewed to ensure they are being followed.

Cobweb Disease

Symptoms

The primary symptom of Cobweb Disease is circular patches of cottony white cobweb-like mycelium growing over casing soil and enveloping mushrooms in its path. The mycelium infects the mushrooms, which can cause them to discolour. Cobweb spores that land on nearby developing mushrooms will cause them to develop brown irregular spotting symptoms, either while they are still growing on the bed or post-harvest.



6. Cobweb growing over brown mushrooms

Cobweb mycelium can develop further on mushrooms post-harvest. When the Cobweb colony has become well established on mushrooms and casing it develops a powdery and granular surface due to the production of masses of dry spores. Sometimes, Cobweb colonies develop a pinky reddish tinge as they get older.

Biology and epidemiology

Cobweb mycelium grows at a rate of at least 1-2cm per day and is favoured by high relative humidity. A small patch will extend rapidly in a few days, engulfing and feeding off any mushrooms in its path. Within a few days, masses of dry powdery spores are produced, which are very easily dislodged by any physical disturbance. If a patch of Cobweb goes unnoticed or untreated then masses of spores will be released into the air when the crop is watered. The dry airborne spores will then be distributed rapidly around the growing room via the air circulation system giving rise to multiple new infection sites, as well as spotted mushrooms, in the next flush. Once airborne, spores will exit growing rooms through open doors and exhaust vents and become incorporated into dust and debris around the farm. From there, they can infect new crops via contaminated equipment and casing, as well as via unfiltered air currents entering rooms during filling or through poorly sealed vents and doors.

Disease treatment

It is very important to identify and treat Cobweb Disease promptly, as its fast growth rate and production of masses of dry spores means it can rapidly escalate out of control. The sooner Cobweb is treated, the fewer spores there will be. Clearly mark all areas to be treated. Cover the Cobweb patches gently to at least 5cm beyond the edge of the patch with strong paper tissue (double thickness) which has been dampened with water for easy handling and positioning. Ensure the edges are well sealed to prevent the dry spores escaping into the air. Historically, inverted plastic containers and salt were used for this purpose. If there are growing mushrooms beneath the paper, try

to break the connection with the casing to stop them growing. Check treated areas regularly to make sure there has been no regrowth nearby.



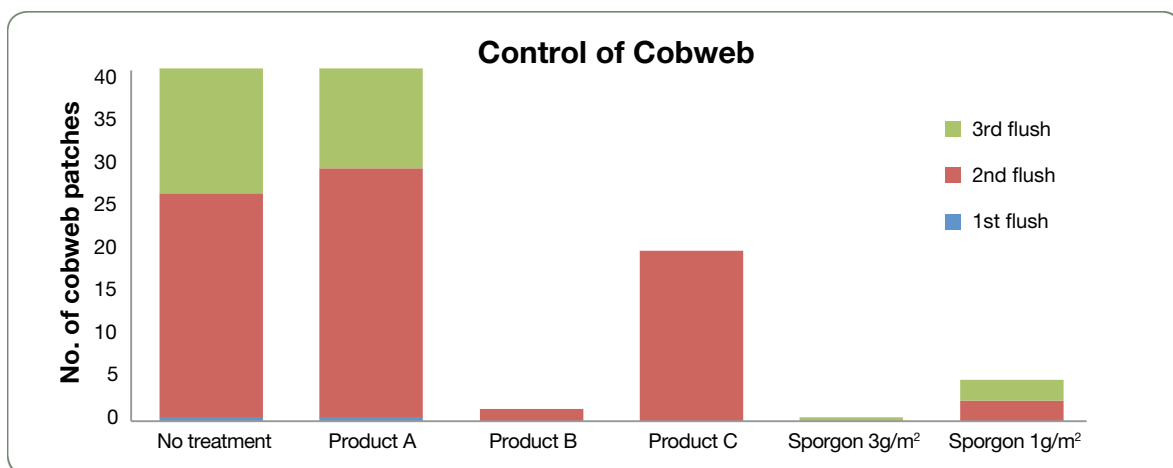
7. Torn plastic covering on end wall

Chemical and biological control of diseases

Few plant protection products are approved for use on mushrooms. Currently, the only fungicide approved for use in most European countries is Sporgon (prochloraz). Reliance on a single product can result in development of resistant pathogen populations and a degree of tolerance to prochloraz has already been identified in some *Lecanicillium* isolates. During the course of the MushTV project, prochloraz gave very good control of *Lecanicillium*, *Mycogone* and Cobweb. However, fungicide use will not be effective

if secondary infections are allowed to develop and get out of control. Thus, it is still important to identify and treat areas of disease as outlined above.

A number of new biocontrol and chemical products were evaluated as part of the MushTV project but most of them gave little or no control against any of the three main diseases, compared to prochloraz. However, one product is showing promise and further information on its efficacy and registration status will be available when the work is completed.



8. Effect of three experimental products and Sporgon (prochloraz) at controlling the development of Cobweb patches over three flushes, as determined in the MushTV project. Please note that product C was only recorded for two flushes and experimental rates were used for Sporgon (prochloraz)

Control of flies

Fly control is critical when trying to deal with Dry Bubble Disease, as flies exacerbate the problem by transporting the sticky spores throughout the farm. Flies can move freely from room to room through open and poorly sealed doors and vents. They can easily contaminate freshly filled and cased growing

rooms, making it very difficult to break the cycle of disease. Sticky fly traps should be used to monitor fly numbers throughout the duration of a crop. Approved fly control products should be used to reduce fly populations. Ensure that rooms are well sealed and that doors are kept closed, where possible.

General disease prevention and control measures

To prevent disease outbreaks occurring it is essential to prevent the buildup of contaminated debris and

dust on surfaces and equipment on the farm. Any disease outbreaks that occur must be identified

and dealt with appropriately to prevent this from happening. This requires many prevention and control measures being permanently in place.

Prevent casing contamination

Many disease outbreaks occur due to the casing becoming contaminated before, during or just after the casing operation. The main sources of contamination are machinery, personnel, dust and flies (which can carry sticky *Lecanicillium* spores). To prevent contamination, all casing equipment should be thoroughly washed and disinfected just before use. The concrete aprons adjacent to casing operations should also be cleaned and disinfected before operations begin and kept damped down to reduce wind-blown dust. Personnel involved in casing operations should have no contact with the rest of the farm before casing operations start, to prevent picking up any contamination. A dedicated changing room for casing operatives is desirable. Only clean overalls and disposable gloves should be worn and a pair of white boots should be reserved for casing operations only, as footwear is a major source of contamination. On large farms, there should be no power-washing occurring while casing is in progress, because this can raise dust, water splash and fine mist that can contaminate newly cleaned surfaces. If casing is to be stored for future use, then ensure it is protected from contamination with dust and flies.

Prevent early crop contamination

There is often a lot of debris on the floor after rooms are filled and cased and this should be cleaned away carefully, using low pressure water and a floor scraper. Sweeping and power washing can raise dust and water splash that can contaminate the freshly cased beds, so these activities should be avoided. Often, disease first occurs near poorly sealed doors and vents, which allow unfiltered contaminated dust and flies to blow in and infect the crop, especially during windy conditions. Doors and vents should be well sealed and doors into growing rooms should be kept shut during case-run and watering to minimise the entry of unfiltered air and flies.

Monitor disease occurrence

Before harvesting begins, trained disease personnel must monitor, record and treat any incidences of disease appearing before the first flush. Disease that occurs before first flush indicates high disease pressure at casing time and a high level of background contamination on the farm. All hygiene measures should be critically reviewed for weaknesses. Harvesters should be encouraged to report disease incidences and be aware of the negative effect that uncontrolled disease outbreaks have on the success of the farm and their jobs. Prevention is better than cure.

Treat disease incidences before watering

Watering over untreated disease is a major cause of disease spread, especially between flushes. Watering will splash disease spores onto adjacent mushrooms and beds, floors, shelving, walls and picking trolleys,

which can then contaminate harvesters' hands, footwear and clothing. Watering should only take place once the crop has been scanned for disease and diseased areas have been treated. The crop should not be watered between flushes if disease levels are high. If Cobweb is present, air circulation fans should be turned off when treating the disease and when watering rooms to minimise the possibility of dispersing the airborne spores around the room.

Limit contamination and spread

Once disease is present on a farm, actions must be taken to limit its spread. Harvesters need to start the day with clean overalls, a supply of disposable gloves and cleaned and disinfected picking tools (knives, buckets, weighing scales). It is good practice to train harvesters to progress from picking first flushes, followed by second flushes and finishing with third flushes, as generally, the first and second flushes are the cleanest. Picking equipment (tables, stools, trolleys, platforms) should not be moved from room to room but remain for the full duration of a crop. Alcohol hand gel should be used on entry and exit to every room to minimise the spread of disease around the farm (especially *Verticillium*) via contaminated hands. Disinfectant foot dips or mats should be placed at the entrance to every room and used on entry and exit from the room to minimise the spread of disease around the farm via contaminated footwear. It is a good idea to gently clean and disinfect growing room floors with low pressure water between flushes to reduce the buildup of contamination.

Where the third flush is heavily infected, consider terminating the crop early or allocate a dedicated picker for third flushes only. Disposable clothing (overalls, gloves, hair net, overshoes) should be used and then placed in disposal bags and left in the room to be cooked out with the crop.

Concrete aprons and floors outside growing rooms should be cleaned and disinfected at the end of every day to kill off any disease spores and contaminated debris coming from diseased growing rooms on footwear and transport trolleys. All growing room door handles – inside and out – should be disinfected every day as well as control panels and other surfaces that are exposed to contamination, such as surfaces in canteen areas, rest rooms and offices (chairs, tables, utensils, door and window handles, lockers, keyboards, etc.).

End of crop routines

The best end of crop treatment is steaming out the room before emptying. Disease levels on farms without steam cook-out are usually much higher and more persistent. Ideally, steam cook-out should be 65-70°C for a minimum of 8 hours to ensure that cooler parts of the room reach adequate temperatures. Concrete floors are unlikely to reach high enough temperatures during cook-out to kill disease pathogens so growing room floors should be cleaned and disinfected thoroughly after emptying, to kill off potential sources of contamination. After emptying, growing room shelves and netting should be cleaned thoroughly to remove debris and disinfected. Cleaned nets should be laid out onto

shelves and the empty growing room and nets should be re-steamed at 65°C for 2 to 8 hours to ensure that any potential residual disease contamination is killed. This is especially important where there have been serious levels of disease in a third flush or when *Trichoderma aggressivum* or Mushroom Virus diseases have been present. Further scientific study is required to determine more precisely the duration of steaming post-emptying required to kill residual pathogens.

Where steam cook-out is not possible, the crop and floors should be sprayed off with an approved disinfectant to give a surface kill of the pathogens, and allowed to stand for an hour before emptying. After emptying, the floors, shelving, netting and walls of the room must be washed and disinfected again. The concrete areas outside the growing room must also be disinfected, as it will have become contaminated by the crop during emptying, especially if diseases have been present. Spent compost must be removed off-site as soon as possible.

Further information

MushTV factsheets

01/15: Use of chemical disinfectants in mushroom production

02/15: Brown Cap Mushroom Virus (associated with Mushroom Virus X) prevention

03/15: Understanding *Trichoderma aggressivum* in Bulk Phase 3 compost

HDC factsheets and publications

09/08: Identification and control of Dry Bubble Disease of mushrooms

10/08: Identification and control of Cobweb Disease on mushrooms

HDC Grower Summeries and Reports

See the HDC website (www.hdc.org.uk) for copies of M 6a, 13, 14a, 14b, 14c, 22, 26a, 30, 31, 33, 33a, 58 and CP4.

Other publications

Mushrooms Pest and Disease Control, A Colour Handbook. Fletcher and Gaze (2008). ISBN: 978-0-12-373984-1 (Academic Press).

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